

BIOLOGICALLY SELF-ASSEMBLED POROUS CERAMIC AS THERMAL INSULATING ADDITIVE IN WATER-BASED PAINT

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ABSTRACT

The interest in porous ceramics has grown rapidly as they have varied properties that can be exploited in many applications. In this study, porous ceramic from rice husk ash was prepared by sol-gel technique using yeast as the pore forming agent. The ceramic has pore volume of $0.3\text{cm}^3/\text{g}$ and surface area of $165\text{m}^2/\text{g}$. Hysteresis loop of the ceramic shows H1 type which indicates that the ceramic is mesoporous. The mesoporosity of this ceramic is an outcome from linking channels and pores with random arrangement of channels due to respiration of the biological agent, yeast. The linking channels in the microstructure of the ceramic can clearly be seen by SEM. The use of the porous ceramic as thermal insulating additive in water-based paint was studied by adding increasing amounts of the ceramic into commercially available water-based paint, mixed well and coated on metal panels. The resultant paint was then characterized in terms of thermal conductivity, k-value. The results proved that the ceramic is a promising material as thermal insulating additive in paint.

INTRODUCTION

It is increasingly difficult to ignore the importance of porous materials in our daily life. Porous ceramics for example, have found a wide variety of applications including filter membranes, catalyst support to biomaterials (scaffolds for bone ingrowth) and as thermal insulator [1-2]. In this paper, porous silica ceramic was synthesized studied as thermal insulating enhancer in paint. The ability of the ceramic to withstand high temperature is a strong reason why was chosen. There are a number of different techniques that can be used to synthesize porous ceramics such as starch consolidation, and gel casting[3, 4].

Sol gel technique is another technique in preparing porous ceramics. It involves three general steps which include gel formation, aging and drying[5] In this paper, sol gel technique using rice husk ash and biological pore forming agent to form porous ceramic is reported. Yeast has been chosen for this process for the ecological concerns. Besides being easy to find and can be obtained at low cost. The use of rice husk ash as silica precursor besides being a cheap and abundant, is an effort to reduce dependence on the use of hazardous and toxic alkoxide [6] and a means of reducing waste production. Wheat particles, poppy seeds, stearic acid and poly methyl methacrylate(PMMA), ammonium bicarbonate and lycopodium spores are among the different types of pore forming agents that have been used lately [7-10] other than yeast.

METHODOLOGY

Sample preparation

Rice husk used in the study was obtained from Kompleks Bernas Sekinchan in Kuala Selangor, Malaysia. The rice husk was first ashed in a furnace at 900°C for 3 hours. Sol-gel processing has been used to prepare silica ceramic by reacting the ash with sodium hydroxide (1M) to form sodium silicate solution. The pH of the solution was then adjusted with sulphuric acid (1M) to form aquagel. Meanwhile, yeast (pore forming agent) was mixed into sugar solution and allowed to rise for about 5 to 10 minutes at temperature of about 45-50°C after which it is mixed with the silica gel. The sugar solution is necessary for yeast to grow and multiply to form porous structure of the ceramic. The activity of the yeast was stopped after 3 hours by heating. The mixture was, filtered, and washed with hot water to remove residual sugar and unreacted yeast and dried in an oven at 110°C for 24 hours. The ceramic was then subjected to heat treatment at 300, 400, 500°C to study the effect of temperature on the pore characteristics of the ceramic. The ceramic was finally heated at 700°C for 2 hours to remove residual sugar, yeast and carbonaceous products.

Sample characterization

The prepared silica ceramic was characterized for pore properties using Brunauer-Emmet-Teller Surface area analyzer (BET Sorptometer BET-201A), microstructure by 1996 LEO Elektronen-Mikroskopi GmbH, Digital Scanning Mikroskop, thermal properties by sdt Q60 Thermal Analysis TA Instrument, bulk density using electronic balance KERN ABJ Balance and thermal conductivity by Thermal Conductivity Testing Equipment.

RESULTS AND DISCUSSION

Thermal analysis

Figure 1 shows the TGA (thermal gravimetric analysis) diagram of dried ceramic i.e. before the removal of the organic matter. There are three main stages of thermal decomposition of the sample. The first corresponding to 10.37 wt. % loss occurred between 50 to 200°C could be assigned to the elimination of moisture in the sample [12-13]. The gradual weight loss at the second stage (temperature from 200-693°C) corresponds to the decomposition of organic matter in the sample. 8.8 wt.% loss occurring between 600-900°C in stage three is attributed to the rearrangement of the inorganic matrix after the burn out of the organic components. The temperatures of the 3 burn out stages were used to study the pore characteristics of the sample.

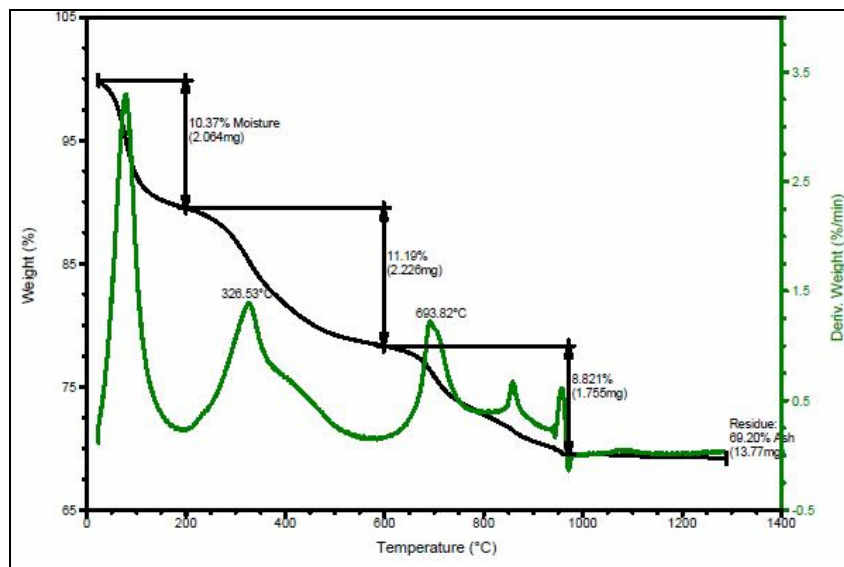


Figure 1: TGA/DTA diagram of sample after drying at 110⁰C for 24 hours (before removal of organic matter)

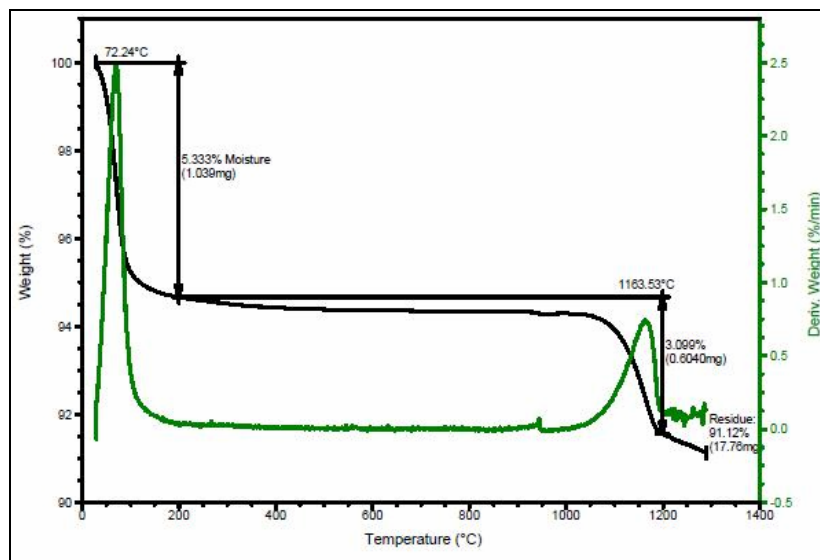


Figure 2: TGA diagram of ceramic burned at 700⁰C for 2 hours (after removal of organic matter)

Figure 2 is TGA/DTA diagram of the ceramic after the removal of the organic matter at 700⁰C, 2 hours. As can be seen, even after the sample was subjected to a high temperature, a weight loss of about 5.3 wt% due to residual moisture could still be detected. However, 91wt.% of the ceramic was stable up to 1000 °C. This suggests that this ceramic could withstand temperature up to 1000⁰C after which the silica ceramic crystallized.

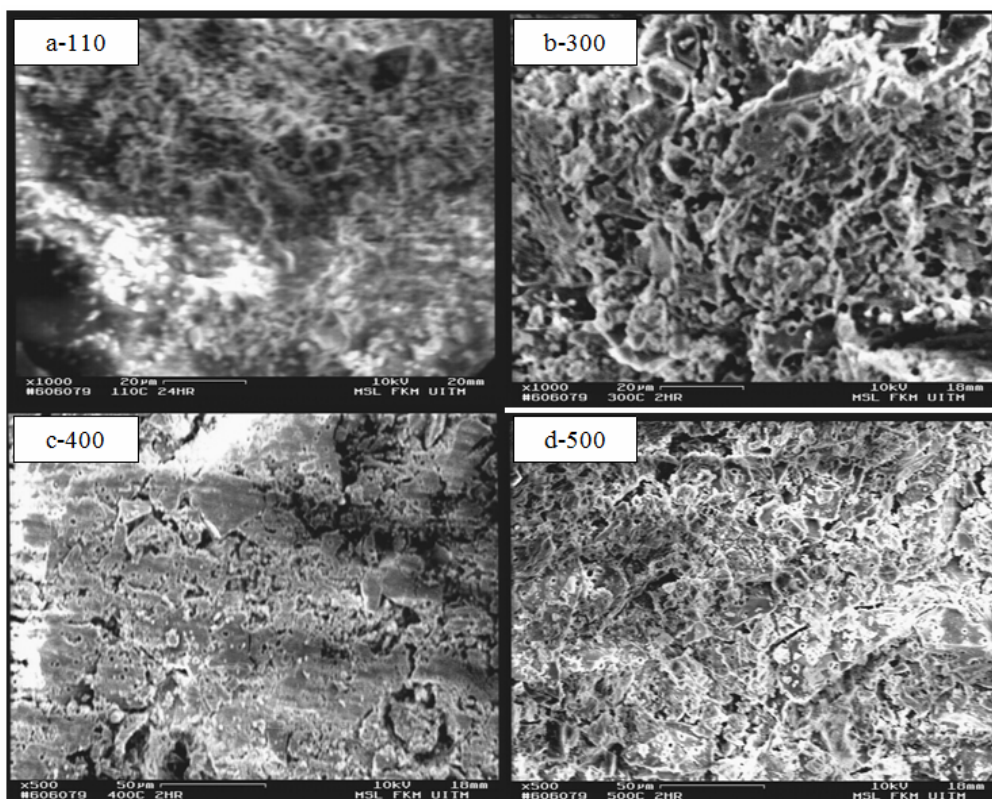


Figure 3: Pore characteristic of ceramic (a) at 110⁰C 24hours (b) 300⁰C 2hours (c) 400⁰C 2hours (d) 500⁰C 2hours

Effect of heating temperature on pore characteristic of ceramic

The temperatures of the three decomposition stages (Figure 1) were used to study the pore characteristics of the sample. The microstructure of the ceramic additive is as shown in Figure 3. In Figure 3(a), the pores could hardly be seen maybe because the bulk of the pore forming agent and other organic matter had not been removed yet. Pores developed when sample was heated at high temperature. Isolated pores were observed at high temperatures after the elimination of the organic matter.

Figure 4 shows the scanning electron micrograph of the ceramic after heating at 700⁰C for 2 hours. From the micrographs, it can clearly be seen that more pores have developed with linking channels. The surface area measured using Brunauer-Emmet-Teller (BET) sorptometer is 165m²/g with pore volume of 0.3cm³/g.

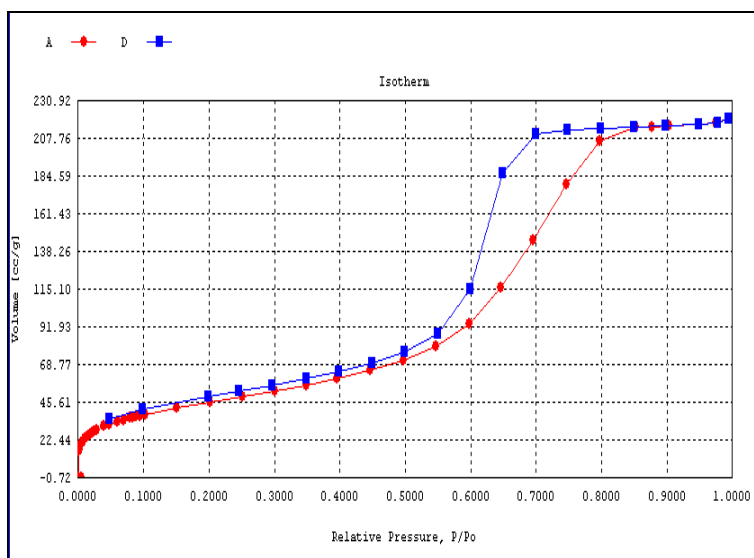


Figure 5: H1 hysteresis loop of the ceramic

The hysteresis loop of the porous ceramic was of H1 type (Figure 5) which indicates that the ceramic is mesoporous [14]. The mesoporosity of this ceramic is an outcome of carbon dioxide gas produced by yeast resulting in linking channels of pores. The more gas produced, the more pores obtained in the ceramics. The pores are randomly distributed throughout the sample. The ceramic not only have a random distribution of particle, but also has various particle sizes ranging from 10-2 μ m, some in sphere shape.

Thermal conductivity of paint

The thermal performance of water-based paint with increasing amounts of the porous silica ceramic added can be seen through the thermal conductivity (k-value) results in Figure 6. A material is considered as thermal insulator if the k-value is less than 1 [15] and for a ceramic, k-value usually lies in the range of 0.5 to 1.5W/mK [16]. Addition of up to 70wt% showed a decrease of up to 98% in thermal conductivity of paint. The paint without ceramic additive exhibits the highest k-value (highest thermal conduction) as compared to ones with ceramic additive. It is evident therefore that by increasing the amount of porous silica ceramic into the paint, the k-value would decrease with respect to temperature. The decrease of k-values with respect to the increase in ceramic additive proves that the additive is the contributor. This is in line result with the TGA/DTA (Section 3.1) results that shows the ceramic to be able to withstand very high temperature.

Figure 7, shows the performance of the paint sample added with varying quantities of porous ceramic additive. The sample with 70wt% porous ceramic additive exhibits the lowest amount of heat passing through compared to the one without proving the insulating capability. The lower the percentage of heat passing through the paint layer, the better the insulating performance.

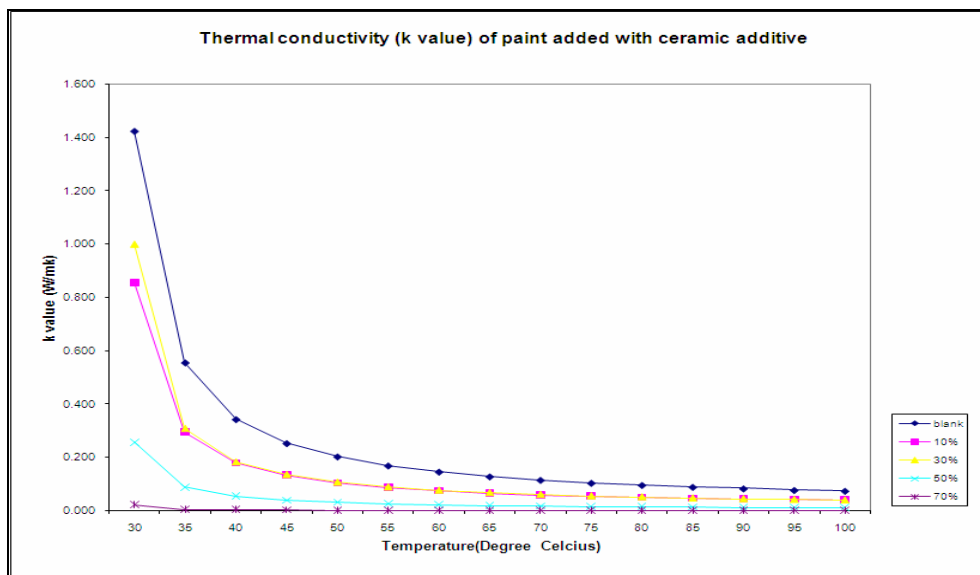


Figure 6: Thermal conductivity (k-value) of paint added with porous silica ceramic as additive

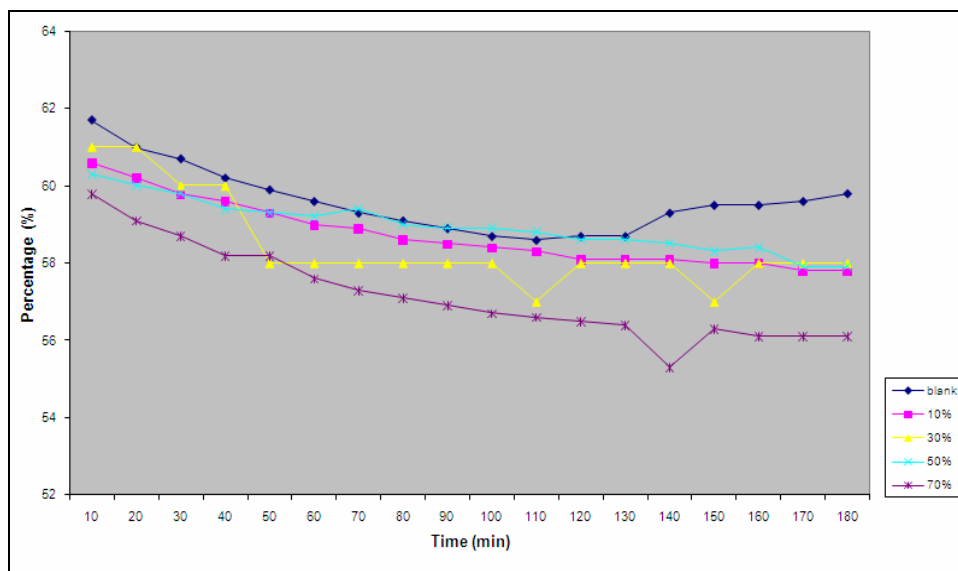


Figure 7: Performance of paint additive at 100°C for 3 hours

CONCLUSION

Porous silica ceramic was synthesized via sol gel method using rice husk ash as precursor and yeast as pore former. Evidence of improved thermal insulating properties was obtained when the ceramic was added into the paint in varying quantities. The ceramic successfully reduced the percentage of heat passing through the paint layer by

4% compared to the one without the porous ceramic.

ACKNOWLEDGEMENT

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REFERENCES

- [1]. Galassi, C., Processing of porous ceramics: Piezoelectric materials Journal of the Europe Ceramic Society, 2006. 26: p. 2951-2958.
- [2]. Gregorová, E. and W. Pabst, Porous ceramics prepared using poppy seed as a pore-forming agent. *Ceramics International*, 2007. 33(7): p. 1385-1388.
- [3]. Fa-Zhi Zhang, T.K., Masayoshi Fuji, Minoru Takahashi, Gelcasting fabrication of porous ceramics using a continuous process. *Journal of the European Ceramic Society*, 2006. 26: p. 667-671.
- [4]. Gregorová, E. and W. Pabst, Porosity and pore size control in starch consolidation casting of oxide ceramics--Achievements and problems. *Journal of the European Ceramic Society*, 2007. 27(2-3): p. 669-672.
- [5]. El-Nahhal, I.M. and N.M. El-Ashgar, A review on polysiloxane-immobilized ligand systems: Synthesis, characterization and applications. *Journal of Organometallic Chemistry*, 2007. 692(14): p. 2861-2886.
- [6]. Soleimani Dorcheh, A. and M.H. Abbasi, Silica aerogel; synthesis, properties and characterization. *Journal of Materials Processing Technology*, 2008. 199(1-3): p. 10-26.
- [7]. K. Prabhakaran, A.M., N.M. Gokhale, S.C. Sharma, Preparation of macroporous alumina ceramics using wheat particles as gelling and pore forming agent. *Journal Ceramic International*, 2007. 33: p. 77-81.
- [8]. Zhang, H.L., J.-F. Li, and B.-P. Zhang, Microstructure and electrical properties of porous PZT ceramics derived from different pore-forming agents. *Acta Materialia*, 2007. 55(1): p. 171-181.
- [9]. Zhang, Y.P., et al., High porosity and large pore size shape memory alloys fabricated by using pore-forming agent (NH_4HCO_3) and capsule-free hot isostatic pressing. *Journal of Materials Processing Technology*, 2007. 192-193: p. 439-442.
- [10]. Z. Zivcova, E.G., W. Pabst, Porous alumina ceramics produced with lycopodium spores as pore-forming agents. *Journal Material Science*, 2007. 42: p. 8760-8764.
- [11]. Wang, Y.H., Y.Zhang, Microstructure control of ceramic membrane support from corundum-rutile powder mixture. *Journal of Powder Technology*, 2006. 168: p. 125-133.
- [12]. D. Predoi, O.C., A. Jitianu, M.C. Valsangiangiacom, et al., Iron oxide in a silica matrix prepared by the sol-gel method.
- [13]. Han, D., Arsenic removal by novel nanoporous adsorbents-kinetics, equilibrium, and regenerability. 2007, Texas A&M University. p. 18.

- [14]. Ahmad Zafir Romli, M.H.A. The potential of natural waste fibre as an energy efficient material for building.
- [15]. Anno Hein, N.S.M., Peter M. Day., et al., Thermal conductivity of archaeological ceramics: the effect of inclusions, porosity and firing temperature. *Thermochimica Acta* 480: p.35-42.